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# Factors associated with subjective shoulder function preoperatively and postoperatively after arthroscopic rotator cuff repair

Yu Ito, RPT, MSc[a,*], Tomoya Ishida, RPT, PhD[a,b], Hisashi Matsumoto, RPT[a], Shota Yamaguchi, RPT[a], Hideki Ito, RPT[a], Naoki Suenaga, MD, PhD[c], Naomi Oizumi, MD, PhD[c], Chika Yoshioka, MD, PhD[c], Shintaro Yamane, MD, PhD[c], Yukiyoshi Hisada, MD[c], Tomoya Matsuhashi, MD, PhD[c]

[a]*Department of Rehabilitation, Orthopedic Hokushin Hospital, Sapporo, Japan*
[b]*Upper Extremity Center of Joint Replacement & Endoscopy, Orthopaedic Hokushin Hospital, Sapporo, Japan*
[c]*Faculty of Health Sciences, Hokkaido University, Sappro, Japan*

A R T I C L E I N F O

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*Level of evidence:* Level IV; Case Series; Prognosis Study

**Background:** Understanding factors associated with improvements in subjective shoulder function after arthroscopic rotator cuff repair (ARCR) helps clinicians identify targets for postoperative rehabilitation. The aim of this study was to investigate the factors associated with subjective shoulder function after ARCR.

**Methods:** Patients who underwent ARCR for rotator cuff tear with at least 12 months of follow-up were included. Subjective shoulder function was assessed preoperatively and at 6 and 12 months postoperatively, using the Shoulder36 (Sh36) 5 domain scores (pain, range of motion [ROM], strength, activities of daily living, and general health). Stepwise multivariable regression analysis was performed to extract the relevant factors for each Sh36 domain score using active shoulder ROM, isometric shoulder and elbow strength, pain score, demographic data, intraoperative findings, medical complications, and cuff integrity.

**Results:** A total of 104 patients met the inclusion criteria for this study. Multivariable regression analysis identified active abduction ROM as the factor associated with 5 Sh36 domain scores at preoperatively. At 6 months postoperatively, isometric external rotation strength at the body side or 90° abduction position, but not the ROM factor, was identified as a significant associated factor with 5 Sh36 domain scores. At 12 months postoperatively, pain score was the most associated factor with pain, ROM, strength, and activities of daily living domain scores of Sh36.

**Conclusion:** Factors associated with subjective shoulder function after ARCR differed between the preoperative and postoperative periods. Postoperative treatment, including rehabilitation, should be modified according to the postoperative period after ARCR.



Rotator cuff tears are prevalent shoulder disorders frequently encountered by clinicians in middle-aged and older adults, resulting in shoulder pain, limited range of motion (ROM), and limited activities of daily living (ADL).[19,22,32,51] Treatment modalities for rotator cuff tears can be either conservative or surgical, and rotator cuff repair is a standard surgical procedure demonstrating favorable outcomes.[9,13] In the last decade, there has been a significant shift from open to arthroscopic procedures for rotator cuff repair, with many surgeons now preferring arthroscopic rotator cuff repair (ARCR) for reparable tears. This approach has yielded predominantly positive clinical outcomes, although some patients experience suboptimal results.[7,12,26,40] Evaluation of clinical outcomes after ARCR includes both clinician-based and patient-reported outcome measures. In the past, clinician-based outcomes have been predominantly used; however, the patient-reported outcomes have recently gained prominence due to their reflection of subjective shoulder function and quality of life,[1,30] which cannot be adequately captured by clinician-based assessments.[4,6,24,41,49] Therefore, identifying factors associated

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*Corresponding author: Yu Ito, RPT, Msc, Department of Rehabilitation, Orthopedic Hokushin Hospital, Kita 8jo Higashi 4chome 1-5, Higashi-ku, Sapporo 060-0908, Japan.

*E-mail address:* y-ito0807@hokushin-hp.or.jp (Y. Ito).

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with subjective shoulder function is crucial to enhancing patient satisfaction after ARCR.

Various patient-reported outcome measures, such as American Shoulder and Elbow Surgeons score, Simple Shoulder Test, Disabilities of Arm, Shoulder, and Hand, and Western Ontario Rotator Cuff index, have been extensively used globally to evaluate patients with rotator cuff tears and repairs.[2,3,4,27] The Shoulder36 (Sh36) questionnaire, developed by the Japanese Orthopaedic Association (JOA) and the Japanese Shoulder Society in 2011, serves as a subjective assessment tool for shoulder function.[28] The Sh36 questionnaire comprises 6 domain scores (pain, ROM, muscle strength, general health, ability of daily living, and ability of sports) derived from 36 questions.[28] This tool is unique in its design to eliminate the effects of hand dominance and gender and to minimize potential confounding effects of pain. It is recommended to evaluate the Sh36 score for each of the 6 domains rather than as a composite score, unlike other patient-reported outcome measures.[28] The Sh36 has demonstrated validity in comparison with other questionnaires, such as the Disabilities of Arm, Shoulder, and Hand[45] and Simple Shoulder Test,[21] and reflects quality of life.[23] It is suggested that the Sh36 may assess postoperative improvements not captured by physician-evaluated metrics, such as the JOA score after arthroscopic rotator cuff surgery.[36] Consequently, the Sh36 is a valuable tool for assessing a patient's subjective shoulder function and quality of life and is widely employed in evaluating patients with shoulder disorders and after shoulder surgery.[20,34,42,43]

As highlighted, it is important to enhance the subjective shoulder function in ADL. Previous studies indicated that it took up to 1 year after ARCR for patient-reported outcomes to surpass the minimum clinically important difference,[39] with potential variances in factors associated with patient-reported outcomes preoperatively and postoperatively.[14,50] Investigating these factors preoperatively and postoperatively is beneficial for postoperative rehabilitation after ARCR. However, to our knowledge, no studies have longitudinally identified factors associated with the subjective shoulder function scores from preoperative to 1 year postoperative after ARCR. This study aimed to longitudinally investigate these factors using Sh36 domain scores as the measure of subjective shoulder function from preoperative to postoperative after ARCR. We hypothesized that the factors associated with subjective shoulder function would be different between the preoperative and postoperative periods.

## Materials and methods

### *Participants*

This study employed a retrospective cohort design. We reviewed the records of 314 patients who underwent ARCR for rotator cuff tear at the author's institution between January 2018 and December 2022. Inclusion criteria were ARCR for partial or small to massive full-thickness rotator cuff tears, excluding isolated or concomitant subscapularis tears. Exclusion criteria were as follows: (1) patients lost to follow-up to within 12 months postoperatively, (2) had a history of shoulder surgery, (3) shoulder disorders other than rotator cuff tear, (4) symptoms due to cervical radiculopathy, and (5) neuromuscular disorders. A total of 230 patients met these criteria. Additionally, patients were excluded from analysis if preoperative and postoperative evaluations at 6 and 12 months were incomplete, or if cuff integrity of repaired tendon at 12 months postoperatively could not be assessed by magnetic resonance imaging. Finally, 104 patients with complete data were analyzed (Fig. 1). Patient's characteristics are presented in Table I. All patients signed an informed consent form, and this study was approved by the Institutional Review Board of our institute (approval number: 2303).

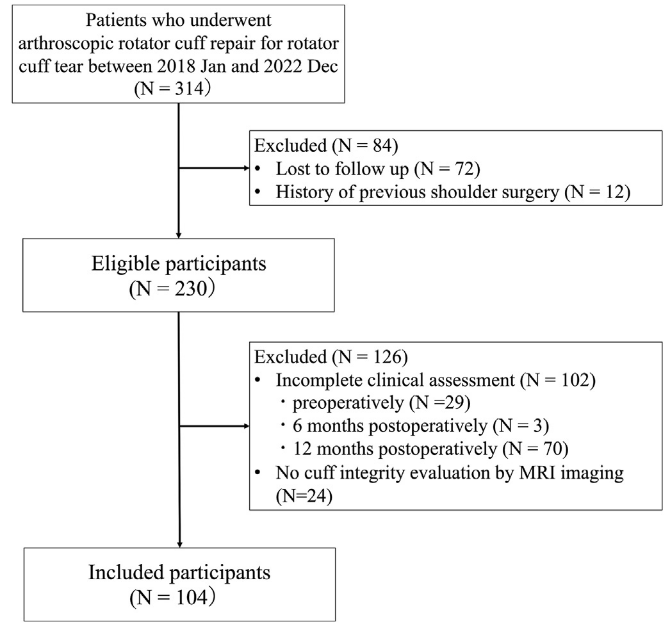


**Figure 1** Flowchart of study enrollment.

### *Surgical procedures*

The ARCR procedures were performed by 6 surgeons at our institution with the patient in the beach-chair position under general anesthesia. The choice of tendon suturing technique was at the surgeon's discretion, with either the surface-holding repair[48] or the suture-bridge technique[37] selected based on intraoperative findings. The number and type of anchors used were also determined according to the condition and mobility of the tendon. The size of the tendon tear was evaluated intraoperatively using the Cofield classification,[10] which defined small tear as < 1 cm, medium tears as 1 to 3 cm, large tears as 3 to 5 cm, and massive tears as < 5 cm. Anterior acromioplasty was performed in all surgeries, and tenotomy of the long head of biceps and glenohumeral joint manipulation, including capsulotomy, were performed as needed (Table I).

### *Postoperative rehabilitation protocol*

The operated arm was immobilized in an abduction pillow brace for the first 6 weeks after surgery. Patients were permitted to perform active elbow ROM, active scapular, and grip exercises from the first day after surgery. Passive-assisted and active-assisted ROM exercises in the supine position were started from 2 days after surgery. Following removal of the shoulder brace immobilization, active ROM exercises below 90° of shoulder elevation were allowed. Antigravity movements above shoulder level were permitted from 8 weeks postoperatively, and resistance exercises with weights and resistance band were allowed from 12 weeks postoperatively. Light work without lifting heavy items was permitted at 3 months, and heavy work and sports activity were allowed from 6 months postoperatively.

### *Outcome measures*

Demographic data (age, sex, and dominance of the operated shoulder) and medical complications such as diabetes mellitus and

**Table I**
Patient's characteristics.

| | N = 104 | % |
|---|---|---|
| Sex | | |
| Male | 45 | (43.3%) |
| Female | 59 | (56.7%) |
| Age (SD) | 64.3 (9.1) | |
| Height (SD) (cm) | 159.6 (9.2) | |
| Weight (SD) (kg) | 64.7 (13.1) | |
| Operation side | | |
| Dominant | 65 | (62.5%) |
| Nondominant | 39 | (37.5%) |
| Tear size | | |
| Partial | 13 | (12.5%) |
| Small | 11 | (10.6%) |
| Medium | 73 | (70.2%) |
| Large | 5 | (4.8%) |
| Massive | 2 | (1.9%) |
| Surgical technique | | |
| Suture bridge | 27 | (25.9%) |
| Surface-holding | 77 | (74.1%) |
| Additional procedures | | |
| LHB tenotomy | 69 | (66.3%) |
| Capsulotomy | 8 | (7.6%) |
| Sugaya type | | |
| 1 | 91 | (87.5%) |
| 2 | 5 | (4.8%) |
| 3 | 2 | (1.9%) |
| 4 | 2 | (1.9%) |
| 5 | 4 | (3.9%) |
| Complications | | |
| Diabetes mellitus | 16 | (15.4%) |
| Hyperlipidemia | 34 | (32.7%) |

*SD*, standard deviation; *LHB*, long head of biceps.

hyperlipidemia were recorded preoperatively. The integrity of the cuff repair was evaluated by magnetic resonance imaging at 12 months postoperatively using the Sugaya classification,[47] with Sugaya type 4 and 5 defined as retear of the repaired tendon (Table I). Shoulder ROM, isometric shoulder and elbow strength, and objective and subjective shoulder function scores using the Sh36 questionnaire were assessed preoperatively and at 6 and 12 months postoperatively.

*Range of motion*

Active and passive ROM of shoulder flexion, abduction, and external rotation at body side and only passive ROM of external and internal rotation at 90° abduction position were measured using a universal goniometer by a physiotherapist in the sitting and supine positions. To score the hand-behind-back motion, we used the subscale of the Constant-Murley Shoulder Score (CSS), assessed by the spinal level reached by the tip of the thumb.

*Isometric shoulder and elbow joint muscle strength*

The isometric strength of shoulder flexion, abduction, external and internal rotation at the body side, external rotation at 90° abduction, elbow flexion, and extension were measured using a hand-held dynamometer (μ-TAS MF-01; Anima Corp., Tokyo, Japan). All muscle strength measurements were performed in the end-sitting position. Flexion and abduction were measured at 45° position, and external rotation at body side and 90° abduction were measured at the neutral position in rotation. Strength measurements in all positions were taken twice, and the largest value was used for analysis. All strength values were normalized by body weight and upper arm or forearm length (N-m/kg).[5,16]

*Objective shoulder function score*

The JOA score (0 to 100−point scoring system) (Appendix 1) and the CSS (0 to 100−point scoring system)[11] were assessed by physiotherapist. Pain severity was assessed using the JOA pain subscale, a 7-point scale ranging from 0 to 30 points in 5-point increments: 30 points for no pain, 25 points for minor pain during sports or heavy work, 20 points for mild pain during work, 15 points for mild pain during daily living, 10 points for moderate pain with occasional night pain with analgesics, 5 points for severe pain with frequent night pain, and 0 point for unable to engage in any activity due to pain.

*Subjective shoulder function score*

The Sh36 questionnaire version 1.3[28] was used to assess subjective shoulder function. The Sh36 is a self-reported questionnaire with high reliability and validity, consisting of 6 independent domains (pain, ROM, muscle strength, general health, ability of daily living, and sports ability).[18,21,45] Each domain score is calculated by averaging the scores of the 36 questions assigned to each domain. Patients rated each question about the affected shoulder on a 5-point scale of difficulty as follows: 4 for no difficulty, 3 for minor difficulties, 2 for some difficulty but manageable on my own, 1 for major difficulties requiring help from someone, and 0 for inability to perform the task. This study used 5 domain scores (pain, ROM, strength, ADL, and health) excluding the sports domain, as many participants were not engaged in sports activities. All questions of the Sh36 are provided in Appendix 2.

*Statistical analysis*

To examine participant characteristics, a 1-way repeated-measures analysis of variance or Friedman test was used to compare the Sh36 domain scores, shoulder ROM, isometric shoulder and elbow strength, and objective shoulder function scores between preoperative and postoperative periods, paired with a *t*-test or Wilcoxon signed-rank test for post hoc analysis. Additionally, ROM, isometric strength, Sh36 domain scores, and other outcome measures were compared at each time point between patients with and without retears using independent *t*-test and Wilcoxon rank sum test.

To identify factors associated with each Sh36 domain score at each time point, a stepwise multivariable regression analysis was conducted with selected independent variables to extract relevant factors for each of the 5 domain scores of Sh36 at preoperatively and 6 and 12 months postoperatively after ARCR. Independent variables for the multivariable regression analysis were selected based on previous studies:[7,8,15,46] active shoulder ROM including hand-behind-back motion, shoulder and elbow joint muscle strength, JOA pain score, tendon tear size, age, sex, medical complication, surgical technique, biceps tenotomy or capsulotomy, and retear of the repaired tendon preoperatively, at 6 and 12 months postoperatively. Sex (1 for male), presence or absence of medical complication (1 for presence), surgical technique (1 for surface-holding technique, 0 for suture-bridge technique), biceps tenotomy or capsulotomy (1 for performing procedures), and retear (1 for retear of repaired tendon) were converted to a dummy variable. Dummy variables were assigned for tendon tear size as follows: 1 for partial-thickness and small full-thickness tears, 2 for medium tears, 3 for large tears, and 4 for massive tears. The dependent variable was each of the 5 Sh36 domain scores preoperatively, at 6 and 12 months postoperatively. Variables with high multicollinearity were retained based on the higher standardized regression coefficient and reanalyzed. A sensitivity analysis, excluding patients with retears or capsulotomy, was also performed to confirm the consistency of the results. All statistical analyses were carried out using R software program (version 4.3.0; R Foundation for Statistical Computing, Vienna, Austria), with the significance level set at .05.

## Results

### *Improvements in shoulder function between preoperative and postoperative periods, and comparisons between patients with retears and without retears*

Six patients (5.8%) were identified with retears of the repaired tendon at 12 months postoperatively (Table I). The results of the preoperative and postoperative outcome measures are shown in Table II. Sh36 domain scores, except for the health domain, were significantly improved throughout 12 months postoperatively. At 12 months postoperatively, all shoulder ROMs were significantly improved compared to preoperatively and 6 months postoperatively. All shoulder and elbow isometric strength were significantly improved at 6 and 12 months postoperatively compared to preoperatively, and except for internal rotation and elbow extension, there were significant improvements at 12 months postoperatively compared to 6 months postoperatively. For shoulder functional score, JOA total score, JOA pain score, and CSS showed significant improvements through 12 months postoperatively.

For comparisons between patients with and without retears, significant differences were found in isometric strength of shoulder flexion and abduction at 12 months postoperatively, but no other significant differences were observed.

### *Factors associated with each Sh36 domain scores at each time point*

Multivariable regression analysis identified active abduction ROM as the most relevant factor in all 5 Sh36 domains preoperatively (pain: $\beta = 0.552$, $P < .001$; ROM: $\beta = 0.563$, $P < .001$; strength: $\beta = 0.677$, $P < .001$; ADL: $\beta = 0.587$, $P < .001$; health: $\beta = 0.451$, $P < .001$) (Table III). In addition, for pain, ADL, and health domains, sex was a significant factor associated with Sh36 score (pain: $\beta = 0.294$, $P = .001$; ADL: $\beta = 0.301$, $P < .001$; health: $\beta = 0.321$, $P < .001$) (Table III).

At 6 months postoperatively, isometric external rotation at body side strength was a significant factor associated with strength and health domain scores of Sh36 (strength: $\beta = 0.292$, $P = .002$; health: $\beta = 0.347$, $P < .001$) (Table IV). For pain, ROM, and ADL domain scores, isometric external rotation at 90° abduction position strength was a significant factor associated with Sh36 scores (pain: $\beta = 0.336$, $P < .001$; ROM: $\beta = 0.333$, $P < .001$; ADL: $\beta = 0.361$, $P < .001$) (Table IV). Additionally, JOA pain score was significantly associated with the Sh36 strength domain score ($\beta = 0.249$, $P = .008$) (Table IV).

At 12 months postoperatively, multivariable regression analysis showed that JOA pain score was significantly associated with pain, ROM, strength, and ADL domain scores of Sh36 (pain: $\beta = 0.265$, $P = .004$; ROM: $\beta = 0.304$, $P = .002$; strength: $\beta = 0.287$, $P = .002$; ADL: $\beta = 0.238$, $P = .013$) (Table V). Furthermore, age was significantly associated with pain, ADL, and health domain scores of Sh36 (pain: $\beta = -0.283$, $P = .002$; ADL: $\beta = -0.232$, $P = .015$; health: $\beta = -0.227$, $P = .018$) (Table V). In the strength and health domain, active abduction ROM was significantly associated with Sh36 scores (strength: $\beta = 0.236$, $P = .012$; health: $\beta = 0.238$, $P = .013$) (Table V).

Multivariable regression analysis, excluding patients with retears or capsulotomy, showed that the same factors were associated with each of the Sh36 domain score as in the analysis including retears or capsulotomy preoperatively, and at 6 and 12 months postoperatively.

**Table II**
ROM, isometric strength, JOA score, CSS, and Sh36 score at preoperatively, 6, and 12 months postoperatively.

| Mean (SD) | Pre OP | PO 6M | PO 12M |
|---|---|---|---|
| ROM (°) | | | |
| Flexion | | | |
| Active | 130.3 (32.0) | 151.3 (12.8)* | 156.1 (11.2)*,† |
| Passive | 145.3 (23.4) | 160.1 (9.8)* | 163.9 (9.6)*,† |
| Abduction | | | |
| Active | 115.2 (42.5) | 149.8 (18.2)* | 156.9 (14.7)*,† |
| Passive | 133.3 (32.5) | 156.9 (15.8)* | 163.9 (12.8)*,† |
| External rotation at body side | | | |
| Active | 47.0 (16.1) | 48.4 (13.7) | 52.1 (12.5)*,† |
| Passive | 50.8 (15.5) | 51.1 (12.9) | 55.4 (12.4)*,† |
| External rotation at 90° abduction | | | |
| Passive | 73.1 (20.3) | 73.8 (14.8) | 80.1 (12.9)*,† |
| Internal rotation at 90° abduction | | | |
| Passive | 41.4 (18.6) | 46.2 (15.1)* | 52.9 (13.9)*,† |
| Hand behind back (points) | 6.7 (2.5) | 7.1 (1.6)* | 8.1 (1.5)*,† |
| Strength (Nm/kg) | | | |
| Flexion | 0.20 (0.11) | 0.26 (0.09)* | 0.29 (0.10)*,† |
| Abduction | 0.17 (0.11) | 0.24 (0.10)* | 0.27 (0.09)*,† |
| External rotation at body side | 0.19 (0.19) | 0.21 (0.07)* | 0.23 (0.07)*,† |
| Internal rotation at body side | 0.25 (0.10) | 0.31 (0.11)* | 0.32 (0.11)* |
| External rotation at 90° abduction | 0.20 (0.09) | 0.25 (0.09)* | 0.28 (0.10)*,† |
| Elbow flexion | 0.33 (0.16) | 0.39 (0.15)* | 0.43 (0.17)*,† |
| Elbow extension | 0.28 (0.12) | 0.34 (0.11)* | 0.35 (0.11)* |
| Functional score | | | |
| JOA total score | 69.4 (13.2) | 87.0 (8.2)* | 91.9 (6.5)*,† |
| JOA pain score | 13.2 (7.1) | 23.6 (6.2)* | 26.3 (4.2)*,† |
| CSS | 52.4 (16.4) | 70.9 (7.9)* | 75.9 (7.7)*,† |
| Sh36 | | | |
| Pain | 2.9 (0.9) | 3.7 (0.4)* | 3.9 (0.3)*,† |
| ROM | 2.9 (1.0) | 3.7 (0.6)* | 3.9 (0.3)*,† |
| Strength | 2.5 (1.2) | 3.6 (0.5)* | 3.8 (0.4)*,† |
| ADL | 3.0 (0.9) | 3.8 (0.4)* | 3.9 (0.3)*,† |
| Health | 3.2 (0.8) | 3.7 (0.3)* | 3.8 (0.4)* |

*SD*, standard deviation; *OP*, operative; *PO*, postoperative; *HBB*, hand-behind-back; *JOA*, Japanese Orthopedic Association; *CSS*, Constant-Murley Shoulder Score; *ROM*, range of motion; *ADL*, activities of daily living; *Sh36*, Shoulder36.
*Means significant difference compared to preoperatively.
†Means significant difference compared to 6 months postoperatively.

## Discussion

This study explored the factors associated with subjective shoulder function as assessed by the Sh36 domain score. The primary findings indicated that factors associated with Sh36 domain scores after ARCR varied between preoperative and postoperative periods. Preoperatively, active abduction ROM and sex were significant explanatory variables for Sh36 domain scores. At 6 months postoperatively, external rotation strength emerged as the most relevant factor in 5 Sh36 domain scores rather than ROM factors. Conversely, at 12 months postoperatively, JOA pain score was significantly most associated with Sh36 domain scores, except for the health domain, whereas shoulder function such as ROM and muscle strength were excluded from the regression models. This study is the first to longitudinally investigate factors associated with subjective shoulder function from preoperative to 12 months postoperative periods following ARCR.

The Sh36 domain scores were used to assess subjective shoulder function, designed to eliminate hand dominance and gender effects and minimize the confounding effects of pain as much as possible. This score is divided into 6 domains to evaluate difficulty in ADL,

**Table III**
Associated factors of each Sh36 domain scores at preoperatively.

| Associated factors | $R^2$ | β | 95% CI | | SE | T value | VIF | *P* value |
|---|---|---|---|---|---|---|---|---|
| | | | Lower | Upper | | | | |
| Pain | 0.385 | | | | | | | |
| Active abduction ROM (degrees) | | 0.552 | 0.381 | 0.723 | 0.002 | 6.412 | 1.000 | <.001 |
| Sex (male = 1, female = 0) | | 0.294 | 0.123 | 0.465 | 0.156 | 3.416 | 1.000 | .001 |
| ROM | 0.308 | | | | | | | |
| Active abduction ROM (degrees) | | 0.563 | 0.374 | 0.752 | 0.002 | 5.934 | - | <.001 |
| Strength | 0.451 | | | | | | | |
| Active abduction ROM (degrees) | | 0.677 | 0.509 | 0.845 | 0.002 | 8.017 | - | <.001 |
| ADL | 0.430 | | | | | | | |
| Active abduction ROM (degrees) | | 0.587 | 0.422 | 0.751 | 0.002 | 7.079 | 1.000 | <.001 |
| Sex (male = 1, female = 0) | | 0.301 | 0.136 | 0.465 | 0.149 | 3.626 | 1.000 | <.001 |
| Health | 0.291 | | | | | | | |
| Active abduction ROM (degrees) | | 0.451 | 0.268 | 0.634 | 0.002 | 4.900 | 1.000 | <.001 |
| Sex (male = 1, female = 0) | | 0.321 | 0.138 | 0.504 | 0.129 | 3.492 | 1.000 | <.001 |

*95% CI*, 95% confidence interval; *SE*, standard error; *VIF*, variance inflation factor; *ROM*, range of motion; *ADL*, activities of daily living; *Sh36*, Shoulder36.

**Table IV**
Associated factors of each Sh36 domain scores at 6 months postoperatively.

| Associated factors | $R^2$ | β | 95% CI | | SE | T value | VIF | *P* value |
|---|---|---|---|---|---|---|---|---|
| | | | Lower | Upper | | | | |
| Pain | 0.104 | | | | | | | |
| External rotation at 90° abduction strength (Nm/kg) | | 0.336 | 0.151 | 0.520 | 0.395 | 3.597 | - | <.001 |
| ROM | 0.167 | | | | | | | |
| External rotation at 90° abduction strength (Nm/kg) | | 0.333 | 0.145 | 0.516 | 0.317 | 3.590 | 1.062 | <.001 |
| Strength | 0.159 | | | | | | | |
| External rotation at body side strength (Nm/kg) | | 0.292 | 0.109 | 0.475 | 0.683 | 3.174 | 1.039 | .002 |
| JOA pain score (points) | | 0.249 | 0.066 | 0.432 | 0.008 | 2.704 | 1.040 | .008 |
| ADL | 0.122 | | | | | | | |
| External rotation at 90° abduction strength (Nm/kg) | | 0.361 | 0.178 | 0.544 | 0.359 | 3.912 | - | <.001 |
| Health | 0.112 | | | | | | | |
| External rotation at body side strength (Nm/kg) | | 0.347 | 0.163 | 0.531 | 0.458 | 3.738 | - | <.001 |

*95% CI*, 95% confidence interval; *SE*, standard error; *VIF*, variance inflation factor; *JOA*, Japanese Orthopaedic Association; *ROM*, range of motion; *ADL*, activities of daily living; *Sh36*, Shoulder36.

**Table V**
Associated factors of each Sh36 domain scores at 12 months postoperatively.

| Associated factors | $R^2$ | β | 95% CI | | SE | T value | VIF | *P* value |
|---|---|---|---|---|---|---|---|---|
| | | | Lower | Upper | | | | |
| Pain | 0.168 | | | | | | | |
| JOA pain score (points) | | 0.265 | 0.086 | 0.444 | 0.007 | 2.935 | 1.008 | .004 |
| Age (y) | | −0.283 | −0.463 | −0.103 | 0.003 | −3.126 | 1.017 | .002 |
| ROM | 0.083 | | | | | | | |
| JOA pain score (points) | | 0.304 | 0.117 | 0.491 | 0.007 | 3.220 | - | .002 |
| Strength | 0.241 | | | | | | | |
| JOA pain score (points) | | 0.287 | 0.112 | 0.463 | 0.009 | 3.252 | 1.013 | .002 |
| Active abduction ROM (degrees) | | 0.236 | 0.052 | 0.419 | 0.003 | 2.551 | 1.107 | .012 |
| ADL | 0.103 | | | | | | | |
| JOA pain score (points) | | 0.238 | 0.052 | 0.424 | 0.007 | 2.541 | 1.007 | .013 |
| Age (y) | | −0.232 | −0.418 | −0.047 | 0.003 | −2.481 | 1.007 | .015 |
| Health | 0.109 | | | | | | | |
| Active abduction ROM (degrees) | | 0.238 | 0.051 | 0.425 | 0.002 | 2.521 | 1.030 | .013 |
| Age (y) | | −0.227 | −0.415 | −0.040 | 0.004 | −2.408 | 1.030 | .018 |

*95% CI*, 95% confidence interval; *SE*, standard error; *VIF*, variance inflation factor; *ROM*, range of motion; *ADL*, activities of daily living; *JOA*, Japanese Orthopaedic Association; *Sh36*, Shoulder36.

offering an advantage over other subjective shoulder assessments by aligning more closely with ADL.[21,28,45] Thus, the Sh36 was deemed an appropriate measure of patient's subjective shoulder function in ADL in this study.

Preoperatively, active abduction ROM was a significant explanatory variable for all 5 Sh36 domain scores. Patients with higher preoperative patient-reported outcomes had significantly higher postoperative outcomes and satisfaction scores and were more likely to achieve the patient-acceptable symptom state after rotator cuff repair.[29] Therefore, preoperative improvements in subjective shoulder function are crucial for achieving favorable postoperative subjective shoulder function. Generally, pain is the primary complaint for patients with rotator cuff tears, influencing the decision to undergo surgery[19] and serving as a prognostic factor for improvement in patient-reported outcome measures.[46] In fact, the study participants experienced moderate pain requiring anti-inflammatory nonsteroidal drugs (mean JOA pain score was 13.2 points). Meanwhile, active abduction is an important movement for performing ADL[35] and is significantly impaired by rotator cuff tears.[31] Thus, based on the results of multivariable regression analysis controlling for other confounding factors, the active abduction ROM was a more critical factor for difficulty in ADL than the degree of pain before ARCR. Additionally, sex was a significant factor associated with subjective shoulder function preoperatively in this study. Previous study has shown that sex can affect subjective shoulder function after ARCR,[44] and this study suggested that it may also influence subjective shoulder function even during the preoperative period. Future investigation is needed in this regard.

On the other hand, at 6 months postoperatively, external rotation strength at body side and 90° abduction position emerged as significant factors associated with 5 Sh36 domain scores in multivariable regression analysis, contrasting preoperative findings where ROM factors were prominent. External rotation strength has been significantly associated with subjective assessment (Western Ontario Rotator Cuff index score) after ARCR.[7,8] Higher external rotation strength relative to abduction strength correlated with a more inferior humerus position relative to the glenoid.[38] Excessive upward translation of the humeral head can cause shoulder impingement symptoms and disrupt centripetal glenohumeral joint motion.[25,33] Therefore, better shoulder external rotation strength can enhance glenohumeral joint motion, reducing difficulty in ADL. Patients after ARCR may improve subjective shoulder function by focusing on enhancing external rotator function during rehabilitation up to 6 months postoperatively.

At 12 months postoperatively after ARCR, the JOA pain score, indicating the degree of pain, was significantly associated with the Sh36 domain scores except for health domain, unlike preoperative and 6-month postoperative findings. Residual postoperative pain is a crucial factor affecting patient's subjective shoulder function and satisfaction after ARCR.[7,15] While shoulder ROM and strength were associated with Sh36 scores preoperatively and at 6 months postoperatively, their sufficient improvement at 12 months postoperatively suggests that the degree of pain, rather than shoulder function, more significantly influences on the difficulty in ADL. Preoperatively, shoulder pain is often the chief complaint, and many patients hope to be pain-free after surgery. The results at 12 months postoperatively indicate that even low-level residual shoulder pain, not requiring analgesics, can impact subjective shoulder function in ADL.

Clinically, understanding the varying factors associated with subjective shoulder function across postoperative period is essential for providing targeted interventions to optimize patient outcomes from preoperatively to 12 months postoperative periods after ARCR. Preoperatively, improving active shoulder abduction ROM is preferable to enhance subjective shoulder function after surgery, avoiding tear progression or pain exacerbation due to overloading. At 6 months postoperatively, in addition to improving ROM, enhancing external rotator muscle strength, such as infraspinatus and teres minor muscles, is crucial to reduce difficulty in ADL. Forward flexion exercise with horizontal abduction loading using a resistance band has been reported to be effective in increasing infraspinatus and teres minor muscle activity,[17] and may be recommended as a home self-exercise. Since the degree of pain is the most influential factor in subjective shoulder function at 12 months postoperatively, clinicians should identify and treat residual pain as early as possible while continuing to improve shoulder ROM and strength from 6 to 12 months postoperatively. In the sensitivity analysis, retear of the repaired tendon was not a significant factor associated with subjective shoulder function after ARCR. Previous study has also reported that retears were not associated with subjective shoulder function after ARCR,[15] and the present study supports these findings. However, as the follow-up period for this study was up to 12 months postoperatively, a long-term follow-up may be needed to investigate the effects of retears.

The present study had several limitations. First, this study was a retrospective cohort study with a small sample size. Future studies with more participants and prospective follow-up would be needed. Second, the present study was a single-center study. Multicenter studies are needed to increase external validity. Third, the variability in patient's rehabilitation visit frequency and duration may have influenced shoulder function improvement. Fourth, a ceiling effect might have occurred due to the 5-point Sh36 score scale from 0 to 4, and the mean scores of each domain at 6 and 12 months postoperatively were high, ranging from 90% to 97% of the full score. Finally, the small number of patients with retears and capsulotomy limited the investigation of retears or capsulotomy impact, necessitating larger samples.

## Conclusion

This study longitudinally examined the factors associated with subjective shoulder function using Sh36 domain scores from preoperative to 12 months postoperative periods after ARCR. The findings revealed that the factors associated with the Sh36 domain scores varied between the preoperative and postoperative periods. Active abduction ROM, external rotator strength, and degree of pain were the primary factors associated with the Sh36 domain scores preoperatively, at 6 months, and at 12 months postoperatively, respectively. Clinicians should tailor their interventions for patients after ARCR at each time point to further enhance subjective shoulder function.

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## Supplementary data

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## References

1. Adomavičienė A, Daunoravičienė K, Šidlauskaitė R, Griškevičius J, Kubilius R, Varžaitytė L, et al. Analysis of functional recovery and subjective well-being after arthroscopic rotator cuff repair. Medicina (Kaunas) 2021;57:715. https://doi.org/10.3390/medicina57070715.
2. Agel J, Hebert-Davies J, Braman JP. American shoulder and elbow surgeons score: what does it tell us about patients selecting operative treatment of a rotator cuff injury? JSES Int 2023;7:751-5. https://doi.org/10.1016/j.jseint.2023.04.007.
3. Angst F, Schwyzer HK, Aeschlimann A, Simmen BR, Goldhahn J. Measures of adult shoulder function: Disabilities of the Arm, Shoulder, and Hand Questionnaire (DASH) and its Short Version (QuickDASH), Shoulder Pain and Disability Index (SPADI), American Shoulder and Elbow Surgeons (ASES) standardized shoulder assessment form, constant (Murley) score (CS), Simple Shoulder Test (SST), Oxford Shoulder Score (OSS), Shoulder Disability Questionnaire (SDQ), and Western Ontario Shoulder Instability Index (WOSI). Arthritis Care Res 2011;63:S174-88. https://doi.org/10.1002/acr.20630.

4. Ardebol J, Ghayyad K, Hwang S, Pak T, Menendez ME, Denard PJ. Patient-reported outcome tools and baseline scores vary by country and region for arthroscopic repair of massive rotator cuff tears: a systematic review. JSES Rev Rep Tech 2023;3:312-7. https://doi.org/10.1016/j.xrrt.2023.05.008.
5. Awatani T, Morikita I, Mori S, Shinohara J, Tatsumi Y. Relationship between isometric shoulder strength and arms-only swimming power among male collegiate swimmers: study of valid clinical assessment methods. J Phys Ther Sci 2018;30:490-5. https://doi.org/10.1589/jpts.30.490.
6. Baumgarten KM. Can the single assessment numeric evaluation be used as a stand-alone subjective outcome instrument in patients undergoing rotator cuff repair? J Shoulder Elbow Surg 2022;31:2542-53. https://doi.org/10.1016/j.jse.2022.05.017.
7. Bejer A, Płocki J, Probachta M, Kotela I, Kotela A. A comparison study of the western Ontario rotator cuff index, and the constant-murley score with objective assessment of external rotator muscle strength and pain in patients after arthroscopic rotator cuff repair. Int J Environ Res Public Health 2023;20:6316. https://doi.org/10.3390/ijerph20136316.
8. Bey MJ, Peltz CD, Ciarelli K, Kline SK, Divine GW, van Holsbeeck M, et al. In vivo shoulder function after surgical repair of a torn rotator cuff: glenohumeral joint mechanics, shoulder strength, clinical outcomes, and their interaction. Am J Sports Med 2011;39:2117-29. https://doi.org/10.1177/0363546511412164.
9. Brindisino F, Salomon M, Giagio S, Pastore C, Innocenti T. Rotator cuff repair vs. nonoperative treatment: a systematic review with meta-analysis. J Shoulder Elbow Surg 2021;30:2648-59. https://doi.org/10.1016/j.jse.2021.04.040.
10. Cofield RH. Subscapular muscle transposition for repair of chronic rotator cuff tears. Surg Gynecol Obstet 1982;154:667-72.
11. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 1987;214:160-4.
12. Danilkowicz R, Levin JM, Crook B, Long JS, Vap A. Analysis of risk factors, complications, reoperations, and demographics associated with open and arthroscopic rotator cuff repair: an analysis of a large national database. Arthroscopy 2022;38:737-42. https://doi.org/10.1016/j.arthro.2021.09.001.
13. Garibaldi R, Altomare D, Sconza C, Kon E, Castagna A, Marcacci M, et al. Conservative management vs. surgical repair in degenerative rotator cuff tears: a systematic review and meta-analysis. Eur Rev Med Pharmacol Sci 2021;25:609-19. https://doi.org/10.26355/eurrev_202101_24619.
14. Gordon D, Pines Y, Alben MG, Ben-Ari E, Rokito AS, Kwon YW, et al. Excellent correlation of the patient-reported outcomes measurement Information system upper extremity score with legacy outcome scores preoperatively and at 1 year after arthroscopic rotator cuff repair. Arthrosc Sports Med Rehabil 2023;5:e315-24. https://doi.org/10.1016/j.asmr.2022.11.021.
15. Harada N, Yano Y, Taneura T, Kudo Y, Yanagihara T, Kawakami J, et al. Six months patient-reported outcomes (Shoulder36) after arthroscopic rotator cuff repair is related to pain. J Phys Ther Fukuoka 2022;35:65-71. https://doi.org/10.57315/fpta.35.0_65. in Japanese.
16. Hébert LJ, Maltais DB, Lepage C, Saulnier J, Crête M. Hand-held dynamometry isometric torque reference values for children and adolescents. Pediatr Phys Ther 2015;27:414-23. https://doi.org/10.1097/PEP.0000000000000179.
17. Ito Y, Matsumoto H, Ishida T, Suenaga N, Oizumi N. Electromyographic activities of glenohumeral joint muscles during shoulder forward flexion with isometric horizontal abduction loading. J Shoulder Elbow Surg 2023;32:1718-27. https://doi.org/10.1016/j.jse.2023.01.006.
18. Ito Y, Amako M, Arino H, Yamamoto K, Nemoto K, Tsuda E. Reliability and validity of shoulder 36 (ver 1.3). Katakansetsu (The Shoulder Joint) 2013;37:851-3. https://doi.org/10.11296/katakansetsu.37.851. in Japanese.
19. Itoi E. Rotator cuff tear: physical examination and conservative treatment. J Orthop Sci 2013;18:197-204. https://doi.org/10.1007/s00776-012-0345-2.
20. Kawabuchi K, Nakamura M. Changes in blood flow in the dorsal scapular artery and relationship to shoulder joint function in rotator cuff tears. JSES Int 2023;7:2356-60. https://doi.org/10.1016/j.jseint.2023.06.018.
21. Kawakami J, Gotoh M, Matsuura K, Shin K, Fujito I, Tanaka A, et al. Usefulness of shoulder36 in rotator cuff tears: comparison with simple shoulder test. J Orthop Surg 2019;27:2309499018819060. https://doi.org/10.1177/2309499018819060.
22. Keener JD, Steger-May K, Stobbs G, Yamaguchi K. Asymptomatic rotator cuff tears: patient demographics and baseline shoulder function. J Shoulder Elbow Surg 2010;19:1191-8. https://doi.org/10.1016/j.jse.2010.07.017.
23. Kumano T, Minamikawa T. Comparison of evaluation using shoulder 36 ver.1.3 and Japan orthopaedic association score. Katakansetsu (The Shoulder Joint) 2013;37:469-72. https://doi.org/10.11296/katakansetsu.37.469. in Japanese.
24. Longo UG, Papalia R, De Salvatore S, Casciaro C, Piergentili I, Bandini B, et al. Minimal clinically important difference (MCID), Substantial clinical benefit (SCB), and patient acceptable symptom state (PASS) of the shoulder Disability questionnaire (SDQ) in patients undergoing rotator cuff repair. Int J Environ Res Public Health 2023;20:5950. https://doi.org/10.3390/ijerph20115950.
25. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. Phys Ther 2000;80:276-91.
26. MacDermid JC, Bryant D, Holtby R, Razmjou H, Faber K, JOINTS Canada, et al. Arthroscopic versus mini-open rotator cuff repair: a randomized trial and meta-analysis. Am J Sports Med 2021;49:3184-95. https://doi.org/10.1177/03635465211038233.
27. Malavolta EA, Yamamoto GJ, Bussius DT, Assunção JH, Andrade-Silva FB, Gracitelli MEC, et al. Establishing minimal clinically important difference for the UCLA and ASES scores after rotator cuff repair. Orthop Traumatol Surg Res 2022;108, 102894. https://doi.org/10.1016/j.otsr.2021.102894.
28. Maruyama K, Kishimoto J, Hara M. A characteristic and the direction for uses of a self-assessment tool for the shoulder "Shoulder 36 Version 1.3." J Jpn Orthop Assoc 2013;87:249-57 (in Japanese).
29. Martin JR, Castaneda P, Kisana H, McKee MD, Amini MH. Preoperative patient reported outcomes Predict postoperative clinical outcomes following rotator cuff repair. Arthroscopy 2023;S0749-8063:00832. https://doi.org/10.1016/j.arthro.2023.10.008.
30. Mercurio M, Castioni D, de Filippis R, De Fazio P, Paone A, Familiari F, et al. Postoperative psychological factors and quality of life but not shoulder brace adherence affect clinical outcomes after arthroscopic rotator cuff repair. J Shoulder Elbow Surg 2023;S1058-2746:00295. https://doi.org/10.1016/j.jse.2023.02.138.
31. Moosmayer S, Tariq R, Stiris M, Smith HJ. The natural history of asymptomatic rotator cuff tears: a three-year follow-up of fifty cases. J Bone Joint Surg Am 2013;95:1249-55. https://doi.org/10.2106/JBJS.L.00185.
32. Moosmayer S, Tariq R, Stiris MG, Smith HJ. MRI of symptomatic and asymptomatic full-thickness rotator cuff tears. A comparison of findings in 100 subjects. Acta Orthop 2010;81:361-6. https://doi.org/10.3109/17453674.2010.483993.
33. Myers JB, Hwang JH, Pasquale MR, Blackburn JT, Lephart SM. Rotator cuff coactivation ratios in participants with subacromial impingement syndrome. J Sci Med Sport 2009;12:603-8. https://doi.org/10.1016/j.jsams.2008.06.003.
34. Nagase Y, Naito M, Momoyama G, Uchida Y, Nishikawa T, Makabe K, et al. Midterm clinical outcomes of reverse shoulder arthroplasty in Japanese patients with rheumatoid arthritis using patient-reported outcome measures (Shoulder36). JSES Int 2021;5:114-20. https://doi.org/10.1016/j.jseint.2020.09.016.
35. Namdari S, Yagnik G, Ebaugh DD, Nagda S, Ramsey ML, Williams GR, et al. Defining functional shoulder range of motion for activities of daily living. J Shoulder Elbow Surg 2012;21:1177-83. https://doi.org/10.1016/j.jse.2011.07.032.
36. Ohno S, Amako M, Arino H, Yamamoto K, Hirahara Y, Nemoto K, et al. Shoulder 36 (ver.1.3) is a region-specific self-administered questionnaire and DASH rotator cuff tear examination of preoperative and postoperative evaluation of surgery. Katakansetsu (The Shoulder Joint) 2015;39:745-8. https://doi.org/10.11296/katakansetsu.39.745 (in Japanese).
37. Park MC, Elattrache NS, Ahmad CS, Tibone JE. "Transosseous-equivalent" rotator cuff repair technique. Arthroscopy 2006;22:1360.e1-5. https://doi.org/10.1016/j.arthro.2006.07.017.
38. Peltz CD, Haladik JA, Hoffman SE, McDonald M, Ramo N, Moutzouros V, et al. Associations among shoulder strength, glenohumeral joint motion, and clinical outcome after rotator cuff repair. Am J Orthop (Belle Mead NJ) 2014;43:220-6.
39. Polce EM, Vadhera AS, Fu MC, Singh H, Haunschild ED, Garrigues GE, et al. Determining the time required to achieve clinically significant outcomes on the PROMIS upper extremity questionnaire after arthroscopic rotator cuff repair. Orthop J Sports Med 2023;11, 23259671231157038. https://doi.org/10.1177/23259671231157038.
40. Sahoo S, Derwin KA, Jin Y, Imrey PB, Cleveland Clinic Shoulder Group, Ricchetti ET, et al. One-year patient-reported outcomes following primary arthroscopic rotator cuff repair vary little by surgeon. JSES Int 2023;7:568-73. https://doi.org/10.1016/j.jseint.2023.03.007.
41. Sahoo S, Stojanovska M, Imrey PB, Jin Y, Bowles RJ, Ho JC, et al. Changes from baseline in patient- reported outcomes at 1 year versus 2 years after rotator cuff repair: a systematic review and meta-analysis. Am J Sports Med 2022;50:2304-14. https://doi.org/10.1177/03635465211023967.
42. Saito K, Kenmoku T, Hirota K, Matsui H. Long-term prognoses of patients with and without re-rupture after arthroscopic rotator cuff repair. J Phys Ther Sci 2021;33:460-5. https://doi.org/10.1589/jpts.33.
43. Sato S, Ukimoto S, Kanamoto T, Sasaki N, Hashimoto T, Saito H, et al. Chronic musculoskeletal pain, catastrophizing, and physical function in adult women were improved after 3-month aerobic-resistance circuit training. Sci Rep 2021;11. https://doi.org/10.1038/s41598-021-91731-0.
44. Shibahashi H, Murakawa M, Yuki I, Uno T, Takakubo Y, Takagi M. Patient sex is a significant factor in arm function recovery after arthroscopic rotator cuff repair. Arthrosc Sports Med Rehabil 2024;6:100834. https://doi.org/10.1016/j.asmr.2023.100834.
45. Shimo S, Sakamoto Y, Amari T, Gemma S. Validation of the shoulder36 for the activities of daily living with shoulder disorders. J Phys Ther Sci 2017;29:635-40. https://doi.org/10.1589/jpts.29.635.
46. Stojanov T, Audigé L, Modler L, Aghlmandi S, Appenzeller-Herzog C, Loucas R, et al. Prognostic factors for improvement of shoulder function after arthroscopic rotator cuff repair: a systematic review. JSES Int 2023;7:50-7. https://doi.org/10.1016/j.jseint.2022.09.003.
47. Sugaya H, Maeda K, Matsuki K, Moriishi J. Functional and structural outcome after arthroscopic full-thickness rotator cuff repair: single-row versus dual-row fixation. Arthroscopy 2005;21:1307-16. https://doi.org/10.1016/j.arthro.2005.08.011.
48. Taniguchi N, Suenaga N, Oizumi N, Miyoshi N, Araki N, Chosa E. Surface-holding repair: an original arthroscopic rotator cuff repair technique. J Shoulder Elbow Surg 2014;23:620-7. https://doi.org/10.1016/j.jse.2014.01.007.

49. Wickman JR, Lau BC, Scribani MB, Wittstein JR. Single assessment Numeric evaluation (SANE) correlates with American shoulder and elbow surgeons score and western Ontario rotator cuff index in patients undergoing arthroscopic rotator cuff repair. J Shoulder Elbow Surg 2020;29:363-9. https://doi.org/10.1016/j.jse.2019.07.013.
50. Wilson CD, Villamaria LJ, Welling BD, Hammonds KA, Robin BN. Resilience correlates with patient-reported outcome measures at a minimum of 2 years after arthroscopic rotator cuff repair. Shoulder Elbow 2023;15:81-6. https://doi.org/10.1177/17585732231170300.
51. Yamamoto A, Takagishi K, Kobayashi T, Shitara H, Osawa T. Factors involved in the presence of symptoms associated with rotator cuff tears: a comparison of asymptomatic and symptomatic rotator cuff tears in the general population. J Shoulder Elbow Surg 2011;20:1133-7. https://doi.org/10.1016/j.jse.2011.01.011.